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MARCH 1963

OOAMA

AIRMUNITIONS TEST REPORT

SHELF AND SERVICE LIFE TEST OF ROCKET MOTORS M16E3 FOR MACE (TM-76)

OGDEN AMA

SHELF AND SERVICE LIFE

TEST OF ROCKET MOTORS,

M16E3 FOR MACE (TM-76)

by

Robert M. Cavett

PUBLICATION REVIEW

This report has been reviewed and is approved

Alex D. Peresich

ALEX D. PERESICH
Chief,
Service Engineering Division
2705th Airmunitions Wing

MARCH 1963

2705TH AIRMUNITIONS WING
OGDEN AIR MATERIEL AREA
AIR FORCE LOGISTICS COMMAND
UNITED STATES AIR FORCE
Hill Air Force Base, Utah

NOTICES

The information furnished herewith is made available for study with the understanding that the Government's proprietary interests in and relation thereto shall not be impaired. It is desired that the Judge Advocate's Office, WCJ, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, be promptly notified of any apparent conflict between the Government's proprietary interests and those of others.

The conclusions and recommendations made in this report are not to be considered directive in nature. This type of information becomes official only when published in Technical Orders or other applicable Air Force documents.

ADMINISTRATIVE DATA

PURPOSE:

This test is one part of a long range program designed to determine the maximum combined service and shelf life of the M16E3 Rocket Motor for the TM76 Missile. This particular phase was to determine if any extension of the present 42 month life was possible.

MANUFACTURER:

Thiokol Chemical Corp, Wasatch Division, Tremonton, Utah

MANUFACTURER'S TYPE OR MODEL NUMBER:

Rocket Motor, Solid Propellant, M16E3, FSN 1336-741-2060-V174

DRAWINGS AND SPECIFICATIONS:

Thiokol Chemical Corp, Model Specification TUS-60-192, Aug 60

Rocket Motor Drawing, Thiokol U-8987

Pyrogen Drawing, Thiokol DU-6670

QUANTITY OF ITEMS TESTED

Five motors were used in this test.

SECURITY CLASSIFICATION:

Unclassified

DATE TEST COMPLETED:

9 August 1962

TEST CONDUCTED BY:

OOAMA (OOYET - 2705th Airmunitions Wing)

Test Director: Richard O. Miller, Capt, USAF

Project Engineer: Robert M. Cavett, Chemical Engineer

DISPOSITION:

All metal parts generated were inspected and certified inert in accordance with Technical Order 11C3-1-3 and HAFBR 136-2 and delivered to the Redistribution and Marketing Division.

ABSTRACT

These tests were accomplished to determine the feasibility of extending the combined service and shelf life of the M16E3 Rocket Motor for the TM-76 Missile system. Inspection, both visual and radiographic, along with static firing was accomplished on five motors, age 52 months. Tests were conducted at -30°F and +160°F. X-ray examination revealed several small propellant defects; they did not have an adverse effect on performance. No malfunctions occurred and ballistic parameters were within specification limits. It is recommended that the combined service and shelf life of the M16E3 Rocket Motor be extended to five years.

TABLE OF CONTENTS

INTRODUCTION

The number and size of solid propellant rocket motors in the Air Force have been increasing at a very rapid rate and it has therefore become more important that the maximum serviceable life of these units be known and fully utilized. Factors such as high reliability and instant readiness have been and still are the prime advantages of the solid propellant motor. These factors must be preserved. To this end the 2705th Airmunitions Wing is performing service engineering and surveillance tests on the explosive components for the TM76A and B Mace Missiles.

From the results of this program, it is hoped that corrective measures for alleviating any adverse aging manifestations may be determined early and thus lengthen the serviceable life of the operational units.

The project covered in this report is part of a continuing surveillance test program and was established to determine the feasibility of an extension in combined service and shelf life of the M16E3 Booster beyond the present 42 months. The motors tested have been installed on Mace missiles deployed in Germany. They have been periodically removed and re-installed during maintenance cycles. No accurate record is available on the total time installed; however, these motors were subjected to field handling, use and storage, and are representative of all motors of similar age.

Static firing facilities located at Hill Air Force Base are limited to firing of rocket motors with a propellant weight of approximately 300 pounds. There is a safety limitation because of buildings in the vicinity of the firing stand that are used for maintenance work. In the event of a malfunction (pressure burst of a large rocket motor) it would be possible for fragments to reach the vicinity of these buildings.

Therefore, it is necessary to conduct tests on the larger motors on the Hill Air Force Range 6404 which is located approximately 45 miles west of Hill Air Force Base. To temperature condition motors prior to static firing, a portable temperature conditioning oven has been procured. This oven has been designed so that it can be transported to the range on a flat-bed truck. It is operated by a portable electrical generator. The oven has a dual capability of temperature conditioning motors either to very high or very low temperatures.

This test was accomplished in accordance with Project M-1-535-Y-2, prepared by the Ground Launch Missiles Branch (OOYEG), Engineering and Test Division (OOYE), 2705th Airmunitions Wing (OOY). Inquiries to this report should be directed to the Ground Launch Missiles Branch. This document is the final report for Project M-1-535-Y-2.

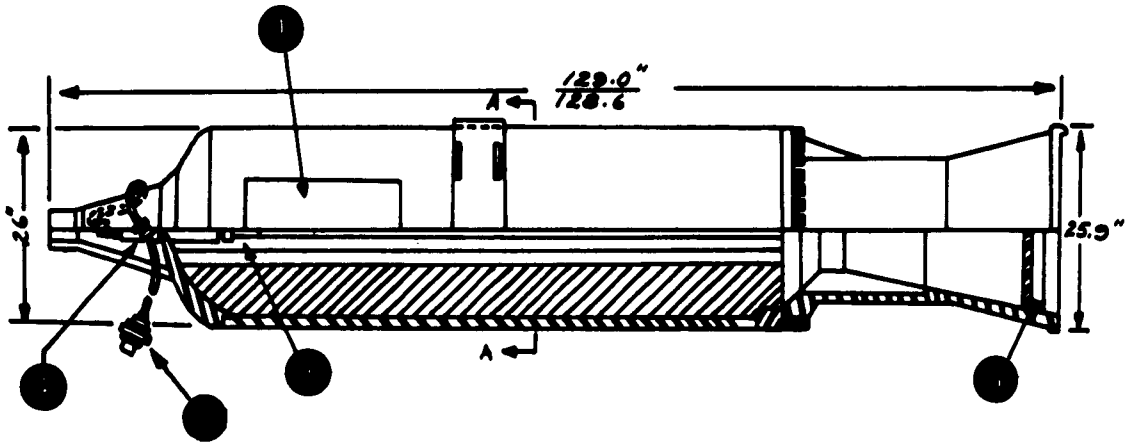
DESCRIPTION

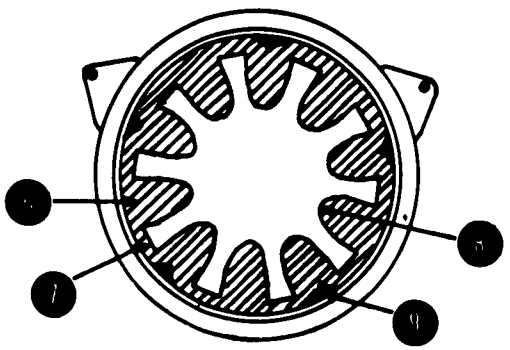
The M16E3 Rocket Motor was designed by Thiokol Chemical Corporation for the TM-76 Weapons System. It produces 101,000 pounds nominal thrust for 2.62 seconds when conditioned to 70°F. The complete booster system consists of the following four major components: motor assembly, pyrogen, safe-arm device and cable assembly.

The motor chamber is fabricated from AISI 4130 steel. The thrust adapter and nozzle are fabricated from AISI 1020 steel. Dimensions of the motor are shown in Figure 1. The TU-P-140 Pyrogen consists of a steel mixed-flow nozzle, steel adapter, and loaded case assembly. Figures 2 and 3 show a cutaway view of the unit and its loaded case assembly. The safe/arm device TU-SA-140 consists of a rotary solenoid-driven arming mechanism, two squibs and a pyrotechnic pellet charge assembled as shown in Figure 4.

The cable assembly used with the M16E3 Motor is a 12-conductor type with cable support clip and cable connectors.

A summary of explosive components used with the TM-76 System is given in Table 1.

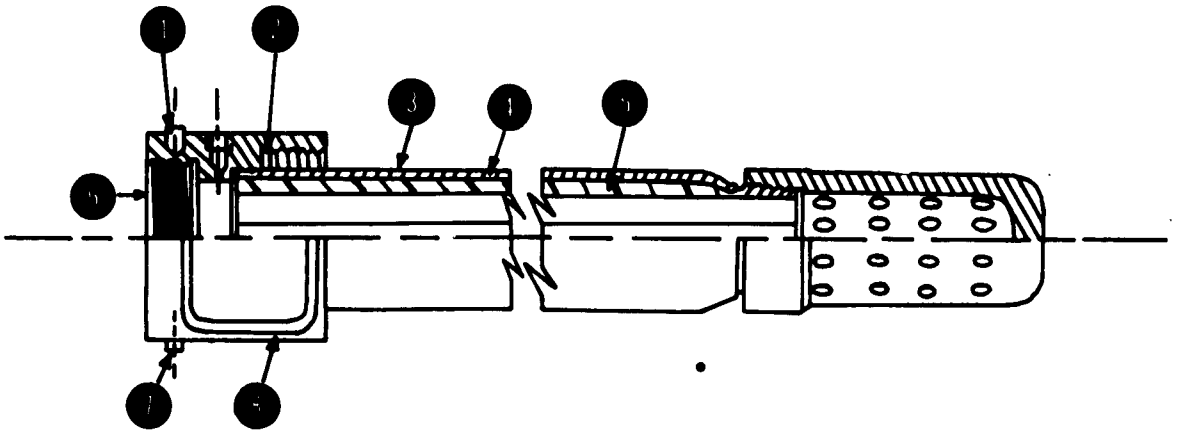




SECTION A-A

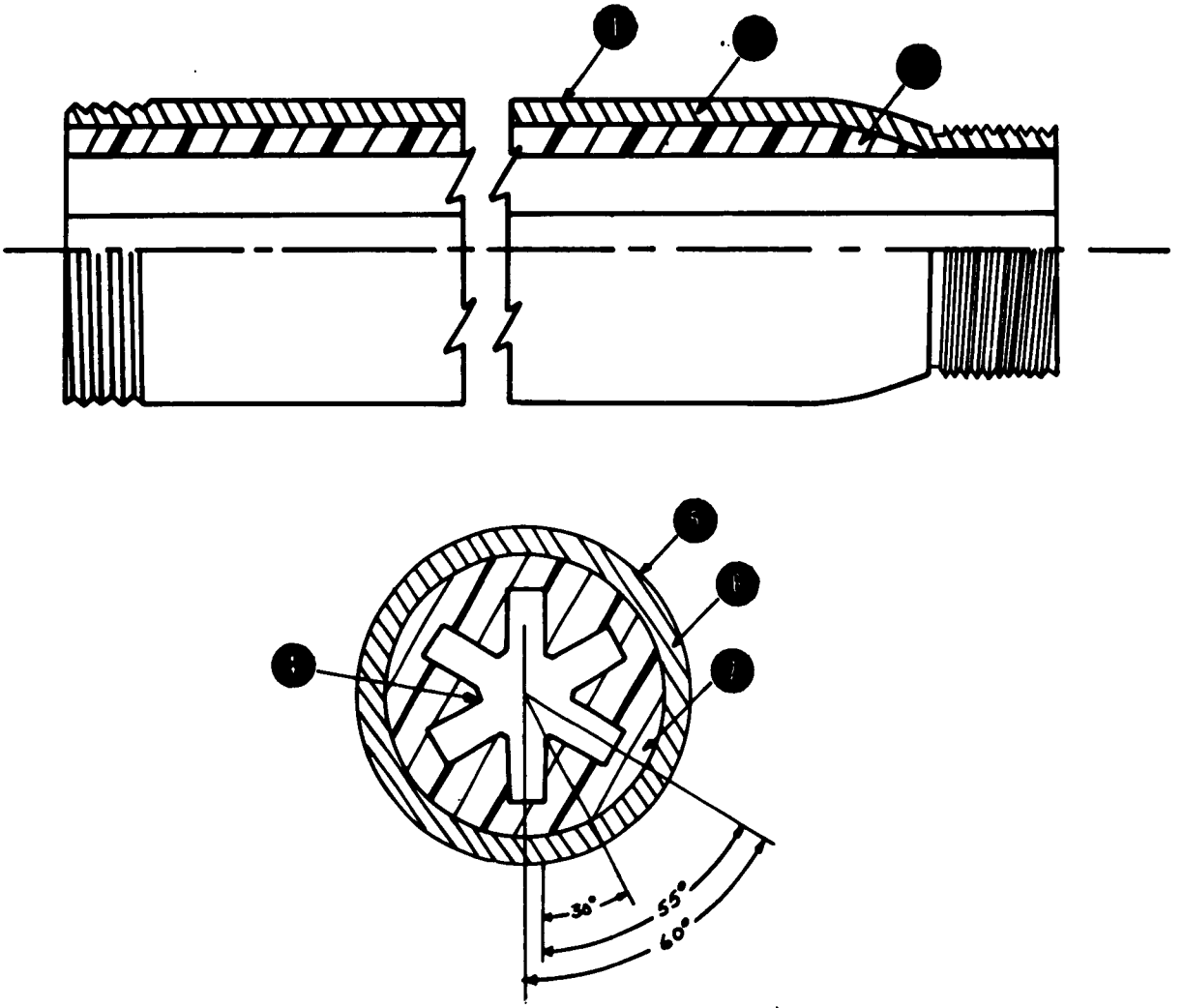
(1) Labels, 180° apart
(2) Cable Assembly
(3) Pyrogen Unit
(4) Safe-Arm Device
(5) Nozzle Closure
(6) Propellant
(7) Web
(8) Star Point
(9) Inhibitor

FIGURE 1. Rocket Motor, M16E3 Showing Dimensions and Important Parts



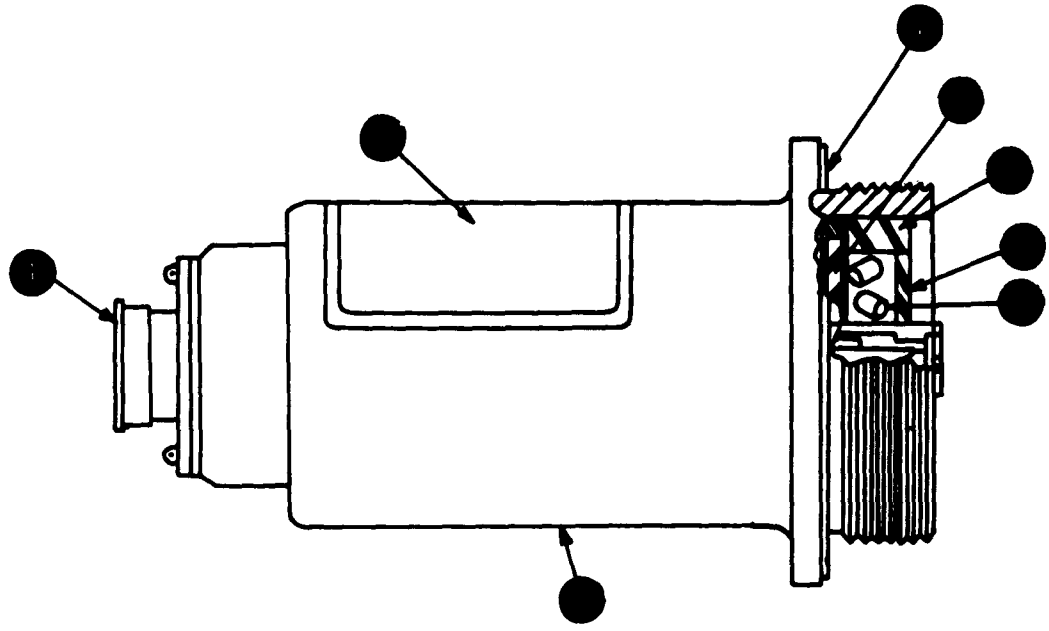
(1) Pin
(2) Gasket
(3) Case
(4) Liner
(5) Propellant
(6) Dust Cap
(7) Pin
(8) Adapter

FIGURE 2. Pyrogen Unit, TU-P-140, Cutaway View



(1) Case
(2) Liner
(3) Propellant
(4) Star Point
(5) Case
(6) Liner
(7) Propellant

FIGURE 3. Pyrogen Unit, TU-P-140, Loaded Case Assembly



(1) Dust Cap
(2) Label
(3) Arming Mechanism Case
(4) Gasket
(5) Disc
(6) Cylinder
(7) Cover
(8) Initiator Charge

FIGURE 4. Safe-Arm Device, TU-SA-140 for M16E3 Motor

ITEM NOMENCLATURE	QUANTITY PER MISSILE	
	TM76A	TM76B
Rocket Motor, M16E3	1	1
Pyrogen Unit, TU-P-140	1	1
Safe/Arm Device, TU-SA-140	1	1
Cap, Blasting Electric E-80	0	4
Cap, Blasting Electric E-81	0	6
Detonating Cord	0	46 Ft 6 In
Squib, Electric, M-76, Mod 1	6	20
Relay, Time Delay, Squib-Operated, Part No. OM373C	0	2
Squib, Rapid Fire, Test Set, Cable Disconnect, 200X-6-134, OA-ANI0-3-(2.7)2(7B1), OA-AN10-3-7B1	1	0

TABLE 1. Explosive Components Used on the TM-76A and B.

A summary of the physical characteristics of the M16E3 Rocket Motor is contained in Table 2.

TECHNICAL DATA	DIMENSION (Inches)
Length of Complete Unit	129.00
Motor Case Outside Diameter	26.00
Maximum Diameter Over Aft Attachment Lugs	33.50
Throat Diameter	10.96
Exit Cone Diameter	25.00
NOMINAL WEIGHT OF ROCKET MOTOR PARTS	**WEIGHT (Pounds)**
Motor Case Assembly including slivers	1005
Nozzle	520
Propellant	1400
Liner	10
Pyrogen Unit	15
Nozzle Closure Plate	5
TOTAL WEIGHT	2955

TABLE 2. Physical Characteristics of the M16E3 Rocket Motor.

The TU-P-140 Pyrogen unit weighs 15.39 pounds, 2.05 of which is propellant. Performance characteristics of the TU-SA-140 safe/arm device are in Table 3.

NOMENCLATURE	REQUIREMENT
Solenoid Actuation	28 Volts DC
Squib Firing Circuit	28 Volts DC
Maximum No-Fire Per Squib or 2 in Parallel	1.0 Ampere
Minimum All-Fire	1.8 Amperes
Resistance (Safe Position) between pins "H" & "L"	3.2 $\pm$ 0.5 Ohm
Single Circuit Between (Pins "A" & "B" - Squib No. 2) (Pins "C" & "D" - Squib No. 1)	0.22 $\pm$ 0.10 Ohm

TABLE 3. Performance Characteristics of the TU-SA-140 Safe/Arm Device.

The propellant used in the M16E3 is the T-35 Polysulfide type. Table 4 gives the composition of T-35 propellant as nominal per cent by weight and the function of each ingredient.

INGREDIENT	NOMINAL PERCENTAGE	FUNCTION
Ammonium Perchlorate with conditioner	70.17	Oxidizer
Liquid Polymer, Ethyl Formal Polysulfide, Medium Viscosity	21.48	Fuel - Binder
Di (Butoxydiethoxy) Methane	2.39	Plasticizer
Ferric Oxide	2.00	Burning - rate Catalyst
Para-Quinone Dioxime	1.60	Curing Agent
Magnesium Oxide, Calcined	1.01	Additive to increase strength at temperature extremes
Diphenylguanidine	0.795	Curing Accelerator
Sulfur	0.015	Curing Accelerator

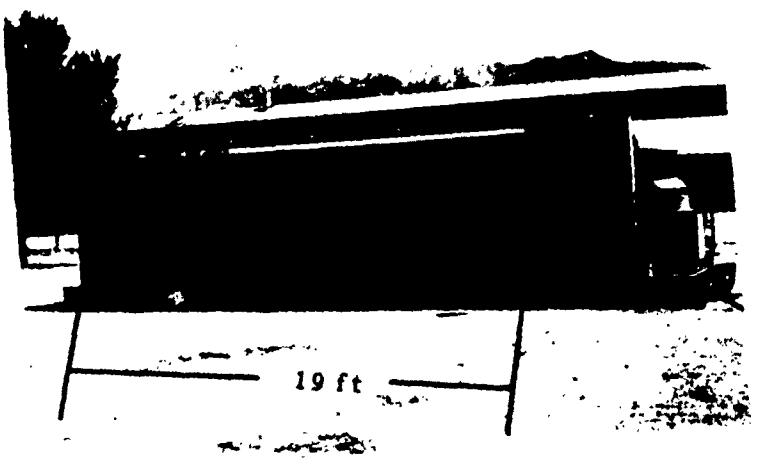
TABLE 4. Propellant T35 Composition.

TEST PROCEDURES

The five test motors (age 52 months) from Lot 1 were subjected to a thorough visual and X-ray examination prior to temperature and static tests.

Temperature conditioning was accomplished using the portable environmental unit shown in Figure 5. Motors were held in the oven for a minimum of 44 hours before firing. Motors 19, 20 and 21 were fired within 60 minutes. Motor number 16 was fired within 80 minutes and number 18 within 100 minutes. The estimated firing temperatures in Table 8 are substantiated by the data.

Test firing was accomplished using the set-up as shown in Figures 6 and 7.



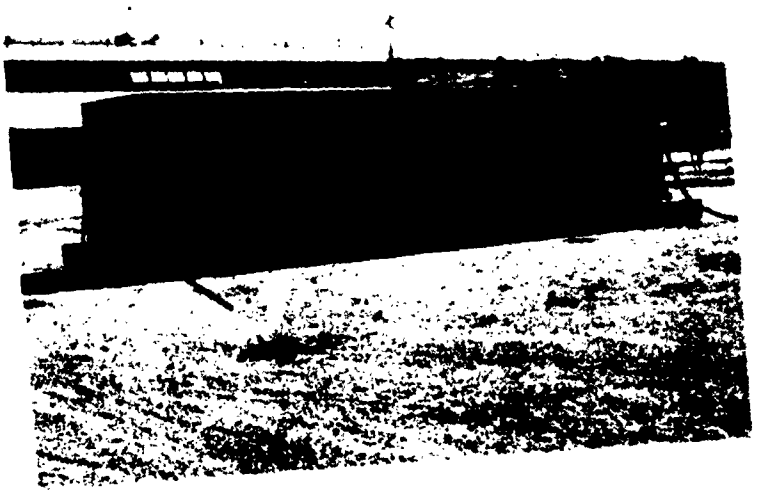


FIGURE 5. Portable Temperature Conditioning Equipment

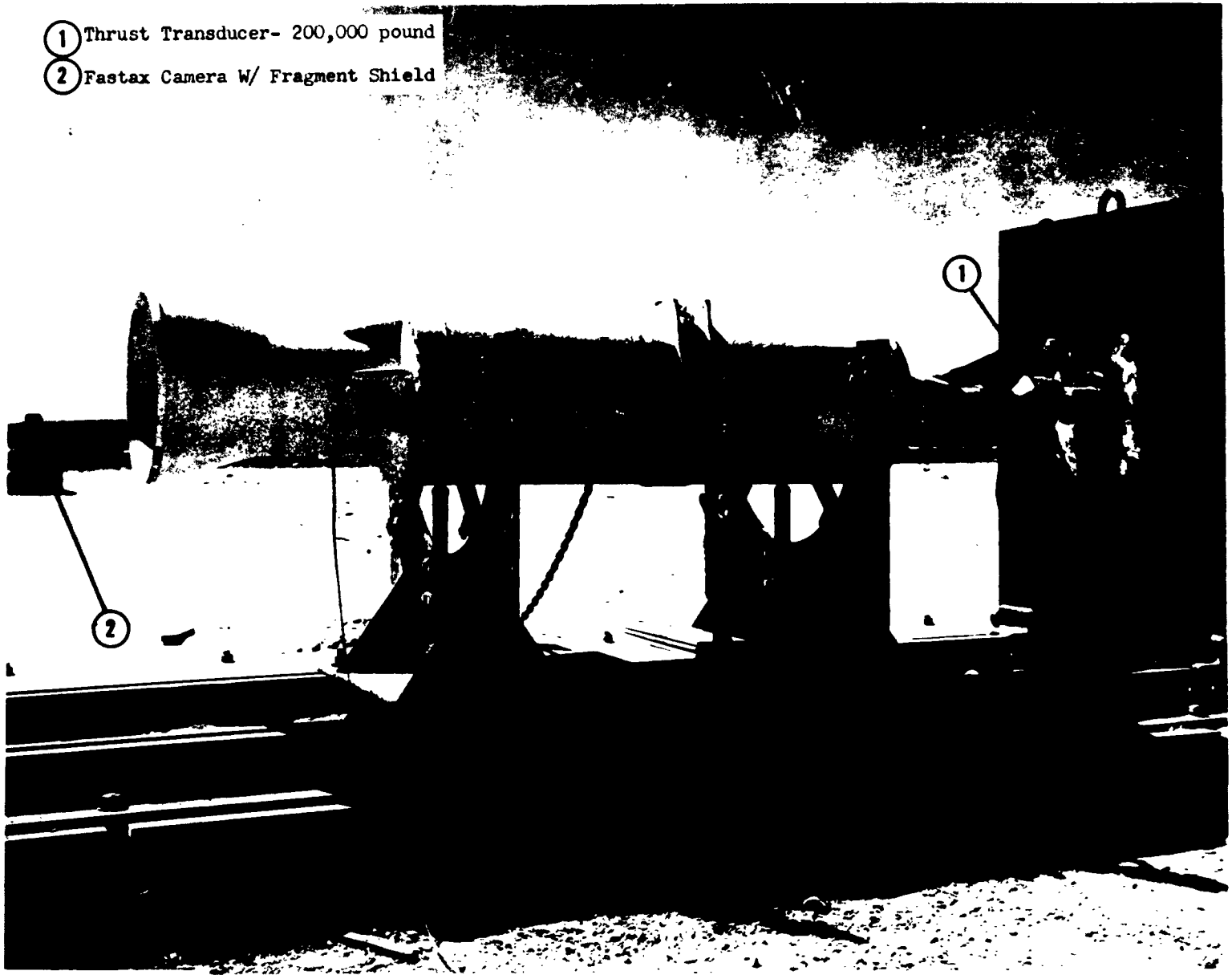


FIGURE 6. M16E3 Motor in Static Firing Stand (Hill Air Force Range 6404)

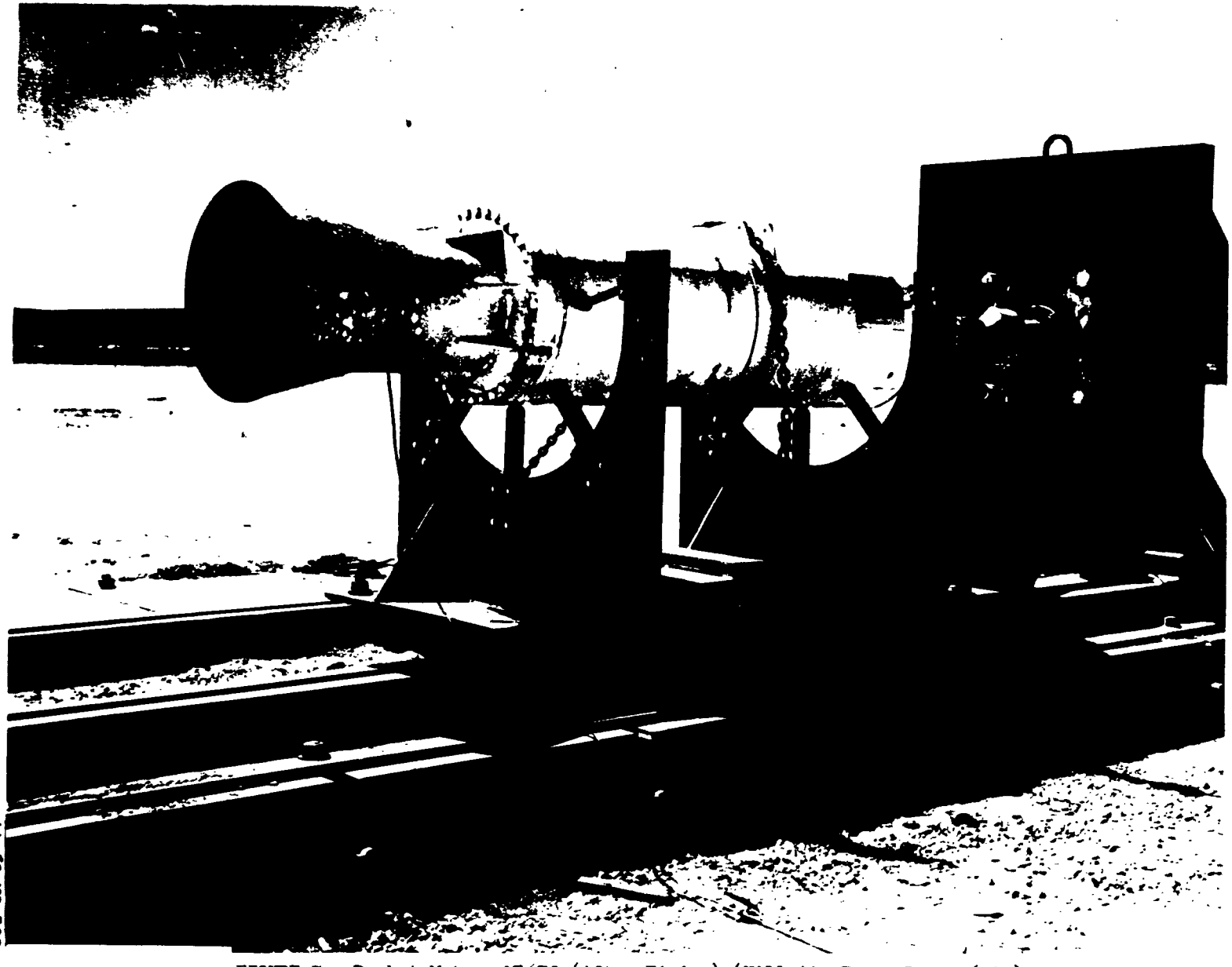


FIGURE 7. Rocket Motor, M16E3 (After Firing) (Hill Air Force Range 6404)

TEST RESULTS

VISUAL INSPECTION

Only a few minor propellant chips were noticed during the visual inspection of the M16 Motors. Visual inspection of the pyrogen units prior to installation in the motors revealed some small chips in the grain.

RADIOGRAPHIC INSPECTION.

A total of 67 voids, chips and defects were found during X-ray examination of the five sample motors. The size of the voids varied from .125 X .125 to 2.0 X 1.5 inches. The surface defects varied from .125 X .25 to 3.0 X 1.5 inches. The breakdown by motor of these voids and defects is in Table 5.

MOTOR SERIAL NO.	SURFACE DEFECTS	VOIDS
16	1	11
18	4	3
19	8	5
20	2	26
21	2	5

TABLE 5. Results of M16E3 Radiographic Examination.

STATIC FIRING.

No malfunctions occurred during the static tests. Thrust values recorded for the two hot motors were slightly low. All other data were within specification limits. Data from three M16E1 Motors are included in the results for comparative purposes. These motors were tested by the Army Rocket and Guided Missile Agency, Redstone Arsenal, Alabama. Figures 9, 10 and 11 are graphical displays of ballistic characteristics for all motors tested. Shown with the Air Force motors are data from motors fired by ARGMA for comparative purposes.

Figure 8 is a graphical definition of the following parameters.

DEFINITION OF PARAMETERS

Ignition Time (t_i). Ignition time is the time from switch closure until 10 per cent of the maximum thrust is attained.

Action Time (t_a). Action time begins when pressure has risen to 10 per cent of its maximum value and ends when it has fallen to 10 per cent of its maximum value.

Burning Time (t_b). Burning time begins at the same point as does the action time and ends when the pressure begins to drop sharply near the end of burning. This point is defined by marking tangents to the equilibrium portion of the curve and to the decay portion of the curve. The angle between these tangents is bisected by a line extending to the curve. A vertical line dropped from the point where the bisecting line cuts the curve indicates the end of burning time.

Ignition Delay (t_d). Ignition delay is the time from switch closure (t_o) to 4000 pounds thrust.

Pressure, Average Chamber ($\bar{P}_c$). The average chamber pressure is the area under the pressure-time curve between the limits of action time divided by the action time (t_a).

Thrust, Average ($\bar{F}$). Average thrust is the total impulse divided by action time.

Impulse, Total (I). Total impulse is the area under the thrust-time curve within the limits of action time.

Impulse, Specific (I_{sp}). Specific impulse is the total impulse divided by the motor propellant weight.

Ignition Interval (t_{pi}). Ignition interval is the time from switch closure (t_o) to 90 per cent maximum pressure. This parameter was not calculated for this report.

Effective Exhaust Velocity (V_e). Obtained by multiplying the specific impulse by 32.2 ft/sec^2.

Average Burning Rate (B_r). Obtained by dividing the web thickness by the burn time.

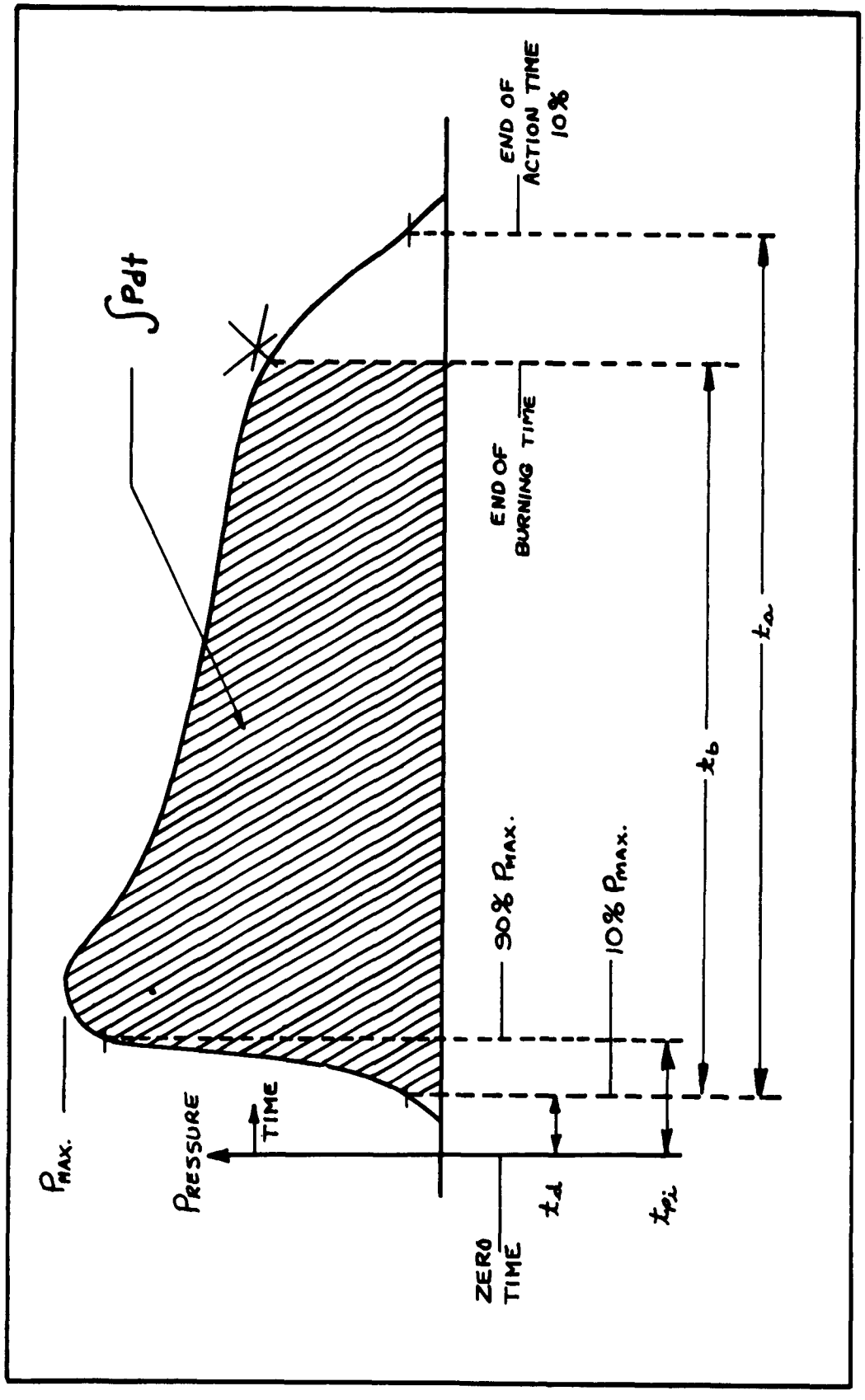


FIGURE 8. Definition of Parameters for the M16E3 Rocket Motor

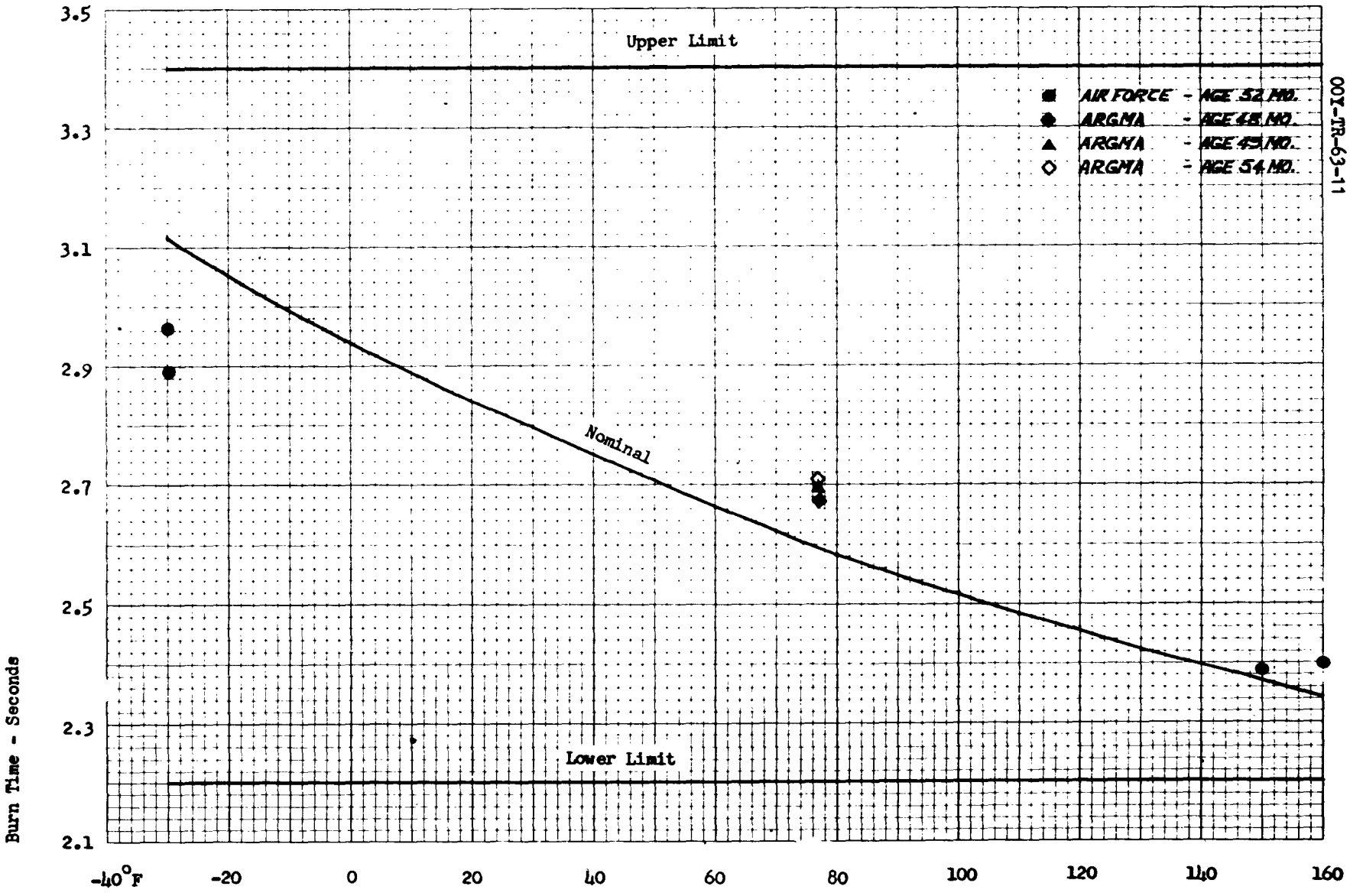


Figure 9. Burn Time versus Temperature for the M16E3 Rocket Motors as Compared to Specification Values.

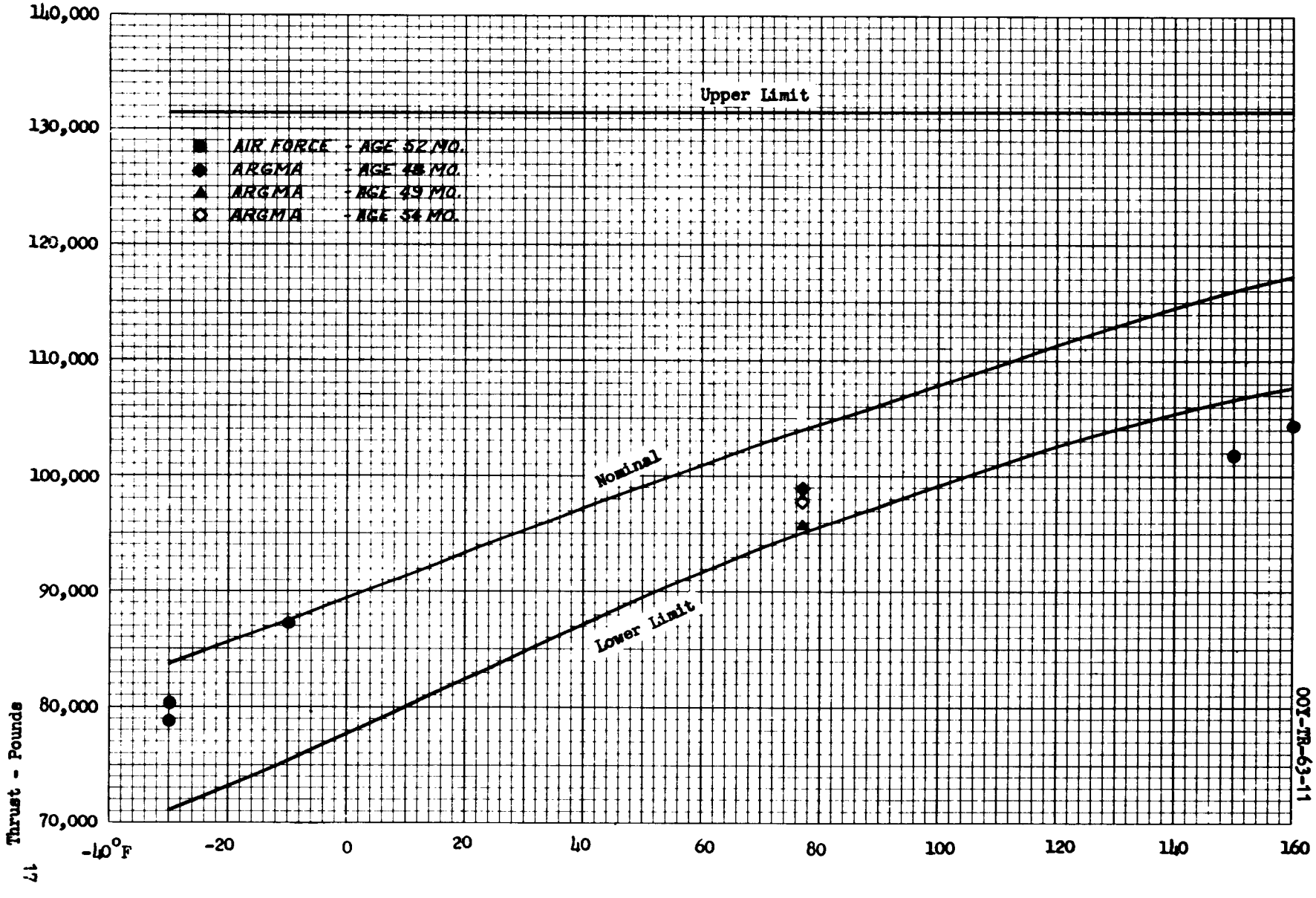


Figure 10. Average Thrust versus Temperature for the M16E3 Rocket Motors as Compared to Specification Values. (Corrected for 4200 ft. Altitude)

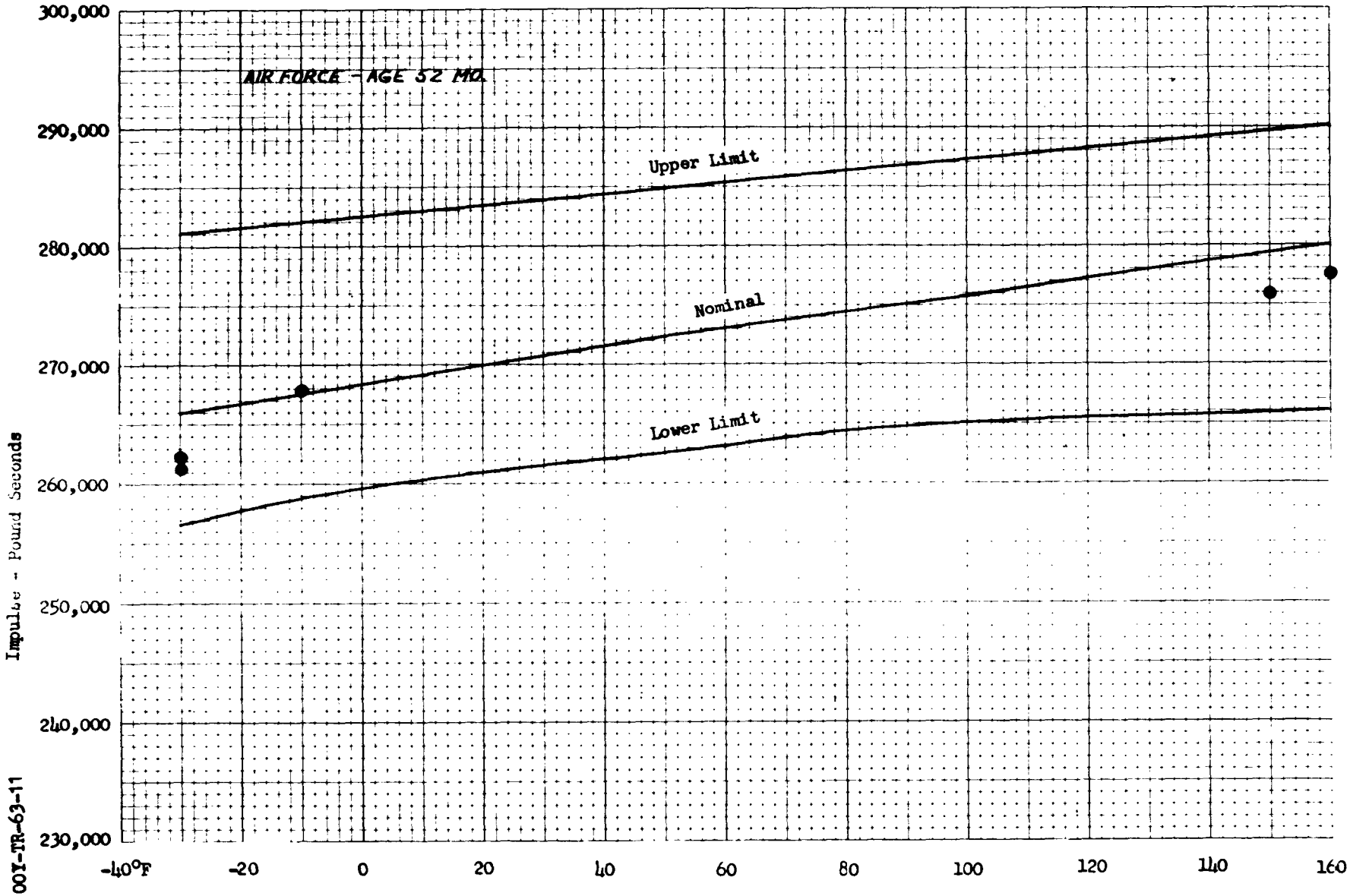


Figure 11. Total Impulse versus Temperature for the M16E3 Rocket Motors as Compared to Specification Values. (not calculated for the ARGMA motors)

Table 6 is a summary of performance specifications for the M16E3 Rocket Motor.

PARAMETER	-30°F	160°F
*Thrust, Average (Min) Pounds	69,500	106,000
*Thrust, Average (Max) Pounds	130,000	130,000
Total Impulse, (Min) Pounds·Sec	256,750	266,000
Total Impulse, (Max) Pounds·Sec	281,000	290,000
Burn Time, (Min) Seconds	2.200	2.200
Burn Time, (Max) Seconds	3.400	3.400
Ignition Delay, (Min) Seconds	-	-
Ignition Delay, (Max) Seconds	0.500	0.500

TABLE 6. Performance Ratings for the M16E3 Rocket Motor.

* Thrust Values are corrected for altitude (4200 feet).

Table 7 contains manufacturer's data for the Air Force Motors tested. Table 8 is a summary of ballistic data for both Air Force and ARGMA firings.

Test system accuracy is $\pm$ 2 per cent; therefore, thrust values for the +160°F motors shown out of specification (Figure 10) may actually be within these limits.

M16E3 ROCKET MOTOR					
	LOT AND NUMBER				
	LOT 1 NO. 20	LOT 1 NO. 21	LOT 1 NO. 18	LOT 1 NO. 16	LOT 1 NO. 19
Mfg Date	3-28-58	3-28-58	3-17-58	3-7-58	3-17-58
Case Number	S-649	S-662	S-656	S-650	S-654
Nozzle Number	S-649	S-662	S-656	S-650	S-654
Propellant Weight	1376	1379	1372	1369	1368
TU-P-140 PYROGEN					
	LOT AND NUMBER				
	THO-005	THO-005	THO-005	THO-005	THO-005
Mfg Date	7-25-61	7-18-61	9-1-61	9-1-61	7-12-61
Serial Number	0290	0272	0311	0316	0239
Sub Lot	042	041	044	044	040
TU-SA-140 SAFE/ARM					
		LOT AND NUMBER			
	THO-006	THO-006	THO-006	THO-006	THO-003
Mfg Date	6-3-61	7-8-61	8-9-61	6-3-61	5-8-61
Serial Number	0137	0208	0227	0141	0098

TABLE 7. Manufacturer's Data - M16E3 Rocket Motor and Ignition System.

	MOTOR LOT AND NUMBER				
	LOT 1 NO. 20	LOT 1 NO. 21	LOT 1 NO. 18	LOT 1 NO. 16	LOT 1 NO. 19
TEMPERATURE (°F)	-30	-30	*-10	*+150	+160
PRESSURE					
P_m (Psi)	673	667	N/A	889	842
P_e (Psi)	573	577	N/A	745	731
THRUST					
F_m (Lb)	94,525	94,525	103,480	124,375	122,385
F_e (Lb)	78,761	80,286	87,109	101,824	104,186
TIME					
t_a (Sec)	3.329	3.256	3.074	2.711	2.665
t_b (Sec)	2.965	2.894	N/A	2.388	2.397
t_d (Sec)	0.240	0.255	N/A	0.100	0.120
t_i (Sec)	0.241	0.266	N/A	0.103	0.124
IMPULSE					
I_e (Lb·Sec)	262,195	261,410	267,773	276,045	277,657
I_{sp} (Lb·Sec/Lb)	190.5	189.6	195.2	201.6	203.0
OTHER					
Burn Rate (In/Sec)	0.629	0.644	N/A	0.781	0.778
Exhaust Vel. (Ft/Sec)	6134	6105	6285	6492	6537

TABLE 8. Performance Data - M16E3 Rocket Motors.

* Estimated Firing Temperature.

CONCLUSIONS

1. The defects found during the radiographic inspection had no significant effect on the performance of the motors.

2. Rocket Motors, M16E3 will perform satisfactorily for more than 42 months when functioned within the temperature limits of -30°F and +160°F.

3. Rocket Motors, M16E3 may be expected to perform with a minimum reliability of 63 per cent at a 90 per cent confidence level. The best estimate of success is 89.7 per cent. The low minimum reliability (63 per cent) stated is mainly due to the small number of units tested, and not because the ballistic data obtained was out of specification.

RECOMMENDATIONS

It is recommended that the combined service and shelf life of M16E3 Rocket Motors be extended to 60 months. Further, recommend that tests be conducted on motors over 60 months old as soon as samples can be obtained.

DISTRIBUTION LIST

3 Dep IG for Safety, Hq USAF (AFIGS-3), Norton AFB, Calif
1 Hq USAF (AFSSS-AE), Wash 25, DC
2 AFLC (MCSW & MCAS), Wright-Patterson AFB, Ohio
1 AUL, Maxwell AFB, Ala
20 ASTIA (TISIA-2), Arlington Hall Stn, Arlington 12, Va
1 Bureau of Naval Wpns (Code RMMO-5), Dep of the Navy, Wash 25 DC
1 CO, US Army Mtel Comd Field Safety Agcy, Charlestown, Ind
1 Safety Div (AMCAD-SA), US Army Mtel Comd, Wash 25, DC
1 US Army Ammunition Procurement and Sup Agcy (SMUAP-Q), Joliet, Ill
1 Hq AFSC (SCMMS-3), Andrews AFB, Wash 25, DC
1 CO, Picatinny Arsenal (Tech Info Lib), Dover, NJ
1 MATS (MAMSS/SBG), Scott AFB, Ill
1 Tech Lib (Code T2), US Naval Propellant Plant, Indian Head, Md
11 OOAMA (1-OOAEP, 1-OOK, 1-OOYIT, 1-OOYID, 1-OOYS, 1-OOYEO, 5-OOYEG), Hill AFB, Utah
1 ASD (ASZSG), Wright-Patterson AFB, Ohio
1 6593d Test Gp (Devel)(DGSMS), Edwards AFB, Calif
1 Allegany Ballistics Lab (Tech Lib), PO Box 210, Cumberland, Md
3 Cml Prpln Info Agcy, The John Hopkins Univ, Applied Physics Lab, (Patrick J. Martin, Asst Gp Suprv), 8621 Georgia Ave, Sliver Spring, Md
1 USAFE (MMD-H), APO 633, New York, NY
1 586th Tactical Missile Gp, APO 109, NY
1 587th Tactical Missile Gp, APO 130, NY
2 AFPR, Martin Co, Baltimore, Md (1 cy to Martin Co TM-76 Program Ofc)
2 AFPR, Thiokol Chemical Corp, Brigham City, Utah (1 cy to Thiokol Chemical Corp)
2 WRAMA (WRW), Robins AFB, Ga

AD

2705th Airmunitions Wing (OOAMA), Hill Air Force Base, Utah
SHELF AND SERVICE LIFE TEST OF ROCKET MOTORS, M16E3 FOR MACE (TM-76),
by Robert M. Cavett, March 1963, 23p incl. figures and tables.
(OOY-TR-63-11) Unclassified Report

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2705th Airmunitions Wing (OOAMA), Hill Air Force Base, Utah
SHELF AND SERVICE LIFE TEST OF ROCKET MOTORS, M16E3 FOR MACE (TM-76),
by Robert M. Cavett, March 1963, 23p incl. figures and tables.
(OOY-TR-63-11) Unclassified Report

These tests were accomplished to determine the feasibility of extending the combined service and shelf life of the M16E3 Rocket Motor for the TM-76 Missile system. Inspection, both visual and radiographic, along with static firing was accomplished on five motors, age 52 months. Tests were conducted at -30°F and +160°F. X-ray examination revealed several small propellant defects; they did not have an adverse effect on performance. No malfunctions occurred and ballistic parameters were within specification limits. It is recommended that the combined service and shelf life of the M16E3 Rocket Motor be extended to five years.

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